ENGINEERING LETTER | 24

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FUNDAMENTALS OF STEAM

INTRODUCTION

A good knowledge of steam heating, for process work and air handling/ventilation systems, is important to design engineers, building owners, and maintenance personnel who may encounter steam systems. This Engineering Letter was written as a basic reference tool, primarily for those who have not been regularly involved in designing and operating steam-heating systems.

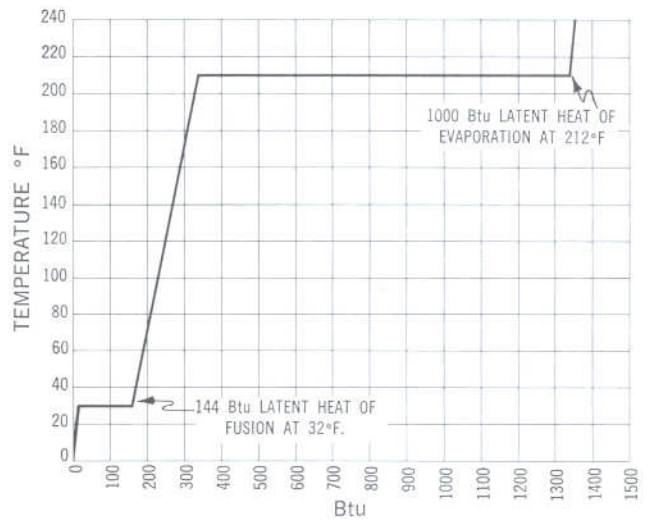
LATENT HEAT

One of the factors important in holding the earth's surface temperature within its rather narrow bounds is the fact that while it takes about 1 Btu to change the temperature of a pound of liquid water by 1 °F., it takes 144 Btu to freeze one pound of water (latent heat of fusion) and about 1000 Btu to convert one pound of water to steam (latent heat of evaporation). The relatively large amount of heat change required to convert water into either ice or steam acts to keep the earth's temperature moderate.

Heating water from 32°F. to its boiling point, 2 12°F. at sea level, requires about 180 Btu per pound (one Btu per degree). This is referred to as sensible heat. Converting the water at 212°F. to steam at the same temperature requires about 1000 Btu per pound. This is the heat applied in a steam boiler.

Conversely, when the latent heat is extracted from the steam, perhaps by condensing it in a section of STEELfin coil, the 1000 Btu per pound is given up by the steam without any change in temperature.

Figure 1 shows how the temperature of one pound of water would vary if subjected to a constant rate of Btu input. Notice that it would stay at 32°F. and 2 12°F. (at sea level) until, in each case the latent heat conversions had taken place for the entire pound of water.



BTU to raise the temperature of one pound of water.
Figure 1

SATURATION

If a container of water is heated sufficiently at a constant pressure, the water temperature will rise until the boiling point is reached. While boiling, the temperature will remain constant until all the water has been converted to steam. Then the temperature will rise again as the steam is further heated, as shown in Figure 1. Steam at the temperature at which it co-exists with water is called *saturated steam.* The temperature is called the *saturation temperature.* The saturation temperature varies with the pressure. An increase in pressure increases the temperature at which the latent heat transfer takes place. The pressure at which the latent heat transfer takes place (at a given temperature) is called the *saturation pressure.*

For example, at sea level normal atmospheric pressure is 14.7 psia (absolute pressure). The saturation temperature is 212°F. At 2 12°F. the saturation pressure is also 14.7 psia (which is also 0 psig see Pressures, below). Almost all useful steam-heat transfer work takes place at the latent heat-saturation temperature and pressure point. Saturation pressures, temperatures, and latent heat values are shown in Figure 2.

Gauge Pressure	Temp. °F.	Latent Heat	Gauge Pressure	Temp. °F.	Latent Heat
2	219	966	80	324	891
5	227	960	90	331	886
10	239	953	100	338	880
15	250	945	110	344	875
20	259	939	120	350	871
25	267	933	130	356	866
30	274	929	140	361	861
40	286	920	150	366	857
50	298	912	175	377	847
60	307	905	200	388	837
70	316	898			

Steam gauge pressures, saturation temperatures, and latent heat values at sea level, standard barometric pressure of 29.92" Hg = 14.7 psia.
Figure 2

PRESSURES

In the English system of measure, steam pressures are measured in pounds per square inch. In international units, steam pressures are measured in pascals or kilopascals where 1 psi is equal to 6894.7 pascals. For the sake of simplicity, English units are used in this Engineering Letter.

There are, necessarily, two reference levels for measuring pressure. One is the pressure above atmospheric. This is the boiler pressure, commonly called *gauge pressure* and abbreviated either psi or psig. Because of the variable nature of atmospheric pressure, steam pressures are more accurately described in terms of their absolute pressure. This is the total amount of pressure above a perfect vacuum. At sea level, atmospheric pressure is 14.7 psia. Hence gauge pressure (psig) + 14.7 = absolute pressure (psia).

SUPERHEAT

Steam is a gas. As in the case of any gas, it can be heated above the boiling point. Once it is past the saturation temperature it requires only about .5 Btu per pound to increase its temperature 1°F.

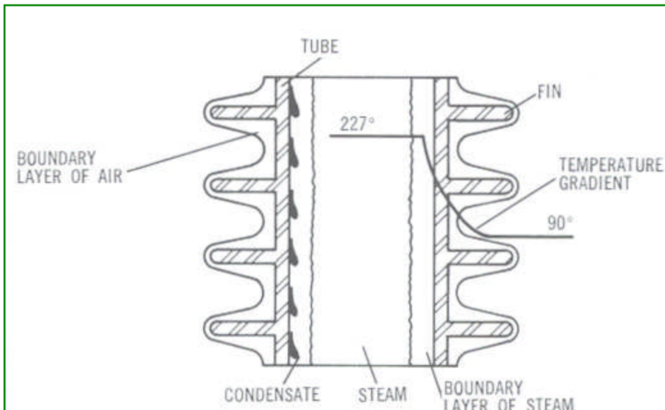
The increase in temperature above the saturation temperature is called *superheat*. Steam that has a small amount of superheat is called *dry steam*. If heated more than a few degrees above the saturation temperature it is referred to as *superheated steam*. Obviously, neither dry nor superheated steam can co-exist with liquid water. Since steam is a gas it tends to expand with a direct relation to temperature. The increased volume and small amount of extra heat value makes superheat a relatively worthless factor in steam heating. Its only real value is to ensure that there will be dry steam at the point where the steam is to be used. In other words, a few degrees of superheat at the boiler will minimize condensation in the supply lines to the steam coils.

CONDENSATION

When steam gives up its latent heat and changes from saturated steam to water at the same temperature, it condenses. The water is referred to as *condensate*.

HEAT TRANSFER

Figure 3 shows the cross section of a typical steam coil. The heat produced by the condensation of the steam travels through the boundary layer of steam, through the condensation that forms on the inside of the tube, through the tube itself, out into the fins, and through the boundary layer of air on the fins' surfaces and into the passing stream of air.



Steam coil cross-section showing the temperature gradient with 5 psig steam (227°F. saturation temperature) heating air to 90°F.
Figure 3

All steam coils are 100% efficient in the sense that the heat released by condensing steam within the coil has nowhere to go but into the air surrounding the coil. Tube-and-fin material, fin spacing, air velocity, and some other factors affect the **rate** at which the heat transfer (and therefore the condensation) takes place but they cannot alter the fact the steam's latent heat has only one place to go: into the airstream.